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Software Should-Cost Analysis With Parametric Estimation Tools

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14. ABSTRACT
In Department of Defense (DoD) acquisition contracts there are often concerns of security and competitive advantage making it difficult to find comparable performance data that may be useful in evaluating contractor proposals. In order for programs to make such comparative evaluations, a should-cost analysis may be conducted. This analysis can be compared to a benchmarking process provided that a benchmark database is available. Parametric estimation tools provide this type of data. This paper shows how SEER-SEM was applied as part of the should-cost effort on the F-22 program. The Office of the Secretary of Defense recognized the resulting $32 million savings in the presentation on Better Buying Power II.

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Preface & Acknowledgements

Welcome to our Tenth Annual Acquisition Research Symposium! We regret that this year it will be a “paper only” event. The double whammy of sequestration and a continuing resolution, with the attendant restrictions on travel and conferences, created too much uncertainty to properly stage the event. We will miss the dialogue with our acquisition colleagues and the opportunity for all our researchers to present their work. However, we intend to simulate the symposium as best we can, and these *Proceedings* present an opportunity for the papers to be published just as if they had been delivered. In any case, we will have a rich store of papers to draw from for next year’s event scheduled for May 14–15, 2014!

Despite these temporary setbacks, our Acquisition Research Program (ARP) here at the Naval Postgraduate School (NPS) continues at a normal pace. Since the ARP’s founding in 2003, over 1,200 original research reports have been added to the acquisition body of knowledge. We continue to add to that library, located online at www.acquisitionresearch.net, at a rate of roughly 140 reports per year. This activity has engaged researchers at over 70 universities and other institutions, greatly enhancing the diversity of thought brought to bear on the business activities of the DoD.

We generate this level of activity in three ways. First, we solicit research topics from academia and other institutions through an annual Broad Agency Announcement, sponsored by the USD(AT&L). Second, we issue an annual internal call for proposals to seek NPS faculty research supporting the interests of our program sponsors. Finally, we serve as a “broker” to market specific research topics identified by our sponsors to NPS graduate students. This three-pronged approach provides for a rich and broad diversity of scholarly rigor mixed with a good blend of practitioner experience in the field of acquisition. We are grateful to those of you who have contributed to our research program in the past and encourage your future participation.

Unfortunately, what will be missing this year is the active participation and networking that has been the hallmark of previous symposia. By purposely limiting attendance to 350 people, we encourage just that. This forum remains unique in its effort to bring scholars and practitioners together around acquisition research that is both relevant in application and rigorous in method. It provides the opportunity to interact with many top DoD acquisition officials and acquisition researchers. We encourage dialogue both in the formal panel sessions and in the many opportunities we make available at meals, breaks, and the day-ending socials. Many of our researchers use these occasions to establish new teaming arrangements for future research work. Despite the fact that we will not be gathered together to reap the above-listed benefits, the ARP will endeavor to stimulate this dialogue through various means throughout the year as we interact with our researchers and DoD officials.

Affordability remains a major focus in the DoD acquisition world and will no doubt get even more attention as the sequestration outcomes unfold. It is a central tenet of the DoD’s Better Buying Power initiatives, which continue to evolve as the DoD finds which of them work and which do not. This suggests that research with a focus on affordability will be of great interest to the DoD leadership in the year to come. Whether you’re a practitioner or scholar, we invite you to participate in that research.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the ARP:

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Software Should-Cost Analysis With Parametric Estimation Tools

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Software Should-Cost Analysis With Parametric Estimation Tools[1]

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Abstract

In Department of Defense (DoD) acquisition contracts there are often concerns of security and competitive advantage making it difficult to find comparable performance data that may be useful in evaluating contractor proposals. In order for programs to make such comparative evaluations, a should-cost analysis may be conducted. This analysis can be compared to a benchmarking process provided that a benchmark database is available. Parametric estimation tools provide this type of data.

This paper shows how SEER-SEM was applied as part of the should-cost effort on the F-22 program. The Office of the Secretary of Defense recognized the resulting $32 million savings in the presentation on *Better Buying Power II*.

Introduction

June 28, 2010, Under Secretary Ashton Carter issued the Better Buying Power memorandum (Carter, 2010) suggesting seven (7) focus topics. “Should-cost analysis” addresses several of the focus areas but most clearly the one Secretary Gates labeled “Incentivize Productivity and Innovation in Industry and Government.” The Department of Defense (DoD) has significant history with should-cost analyses. A RAND study (Boito, 2012), examined this history from the 1970s to today. The RAND study finds support for this analysis in the Federal Acquisition Regulations (FAR) as follows:

> Should-cost analysis as described in the FAR is a specialized form of cost analysis, used to support contract negotiations, that is characterized by a focus on the elimination of contractor inefficiencies. It is significant that the guidance for should cost analysis is found in the federal regulation for the contracting function, because contracting is the process by which the government specifies what it wants to buy and at what price. (Boito, 2012, p. 41)

In this study, RAND observes that a should-cost analysis requires participation of both contractors and government personnel. Successful negotiation can only be achieved when the contractor agrees to the objectivity of government observations and the contractor believes it can eliminate the inefficiency. The negotiation task is often difficult because the government is frequently in a position of having a single source supplier. The single-source situation may make it difficult for the government to persuade the contractor to participate openly in the should-cost analysis. Any lack of openness or access to data will limit the government's ability to identify the inefficiencies.

A major challenge in conducting a should-cost analysis is the skill required of the analysts. The team doing the analysis must encompass skills in pricing, contracting, program management, and subject matter expertise in areas relevant to the program (Boito, 2012, p. x). This team must have both depth of knowledge in the focus disciplines and breadth of experience across programs and industry. Finally, they must be able to apply these skills to present an objective set of recommendations accessible to both program management and contractor.

The Software Engineering Institute (SEI) has participated in some should-cost analyses using parametric software cost estimation tools. This paper describes the methodology and some results. The following section describes the methodology. Then next section discusses an example application and results synthesized from multiple cases. The final section provides lessons learned and ideas for future improvements.

SEI Should-Cost Methodology

The DoD may have gotten an early start on everyone with "should-cost analysis," but the commercial world has pursued the topic extensively under the label of "benchmarking." An early book on the subject is *Benchmarking: The Search for Industry Best Practices That Lead to Superior Performance* by R.C. Camp (Camp, 1989). Just a year later, James Womack, Daniel T. Jones, and Daniel Roos (1990) described Toyota's use of benchmarking in *The Machine That Changed the World*. In the 1990s, corporate benchmarking was a popular consulting business.

The SEI should-cost work stemmed directly from SEI experience with benchmark databases in the form of parametric cost estimation tools. Using the parametric estimation tools is not quite the same approach as traditional benchmarking, but the cost of this approach is modest and works well considering the resistance to traditional benchmarking in the DoD acquisition context.

Five steps are required to prepare a should-cost proposal using parametric estimation tools.

Step 1: Develop a detailed understanding of the proposer's estimate. Include product scope, architecture, and methods of development by reviewing the proposal and proposer's basis of estimate.

Step 2: Use a parametric estimation tool to develop an estimate that matches the proposer's estimate as closely as possible. Estimates of size must match exactly.

Step 3: Perform a sensitivity analysis to identify the productivity factors having the greatest effects on program performance.

Step 4: Prepare an alternative estimate with the adjusted parameters. Develop a briefing demonstrating the changed parameters and new estimate.

Step 5: Conduct a workshop to help the contractor plan potential performance improvements.

Step 1: Develop a Detailed Understanding of the Proposer's Estimate

This step will require access to many details of the contractor's basis of estimate and some interviews with the contractor's staff. This step requires access to the program management and engineering staff who provided the size, product complexity, and project environment factors used for the estimate. Usually, the interviews will require a full day and may require an additional phone call to understand the contractor's meaning and intent for some data. Analyzing the basis of estimate may require as much as five to seven days in total. Understanding the scope of work and complexity of the proposed product is not easy since the WBS (e.g., task sheets) structure of the proposal may cause parts of the estimate to be represented in several different sections.

- Begin preparation by reviewing product requirements, including proposed product architecture. Identification of complexity factors such as aggressive key performance measures, safety, interfaces, and others will be essential to preparing the estimate.
- Provide the contractor with requirements for data and interviews.

With the contractor, complete the following:

- Review analogies used for developing the size estimate. Did setting the size follow a standard procedure used previously by the company? Is there any reason the size would have been adjusted to meet a target price? Use these factors to set a potential range for the size estimate.
- Check the scope definition to see which components and work products will be delivered and to whom they will be delivered. Count every delivery outside the development team (e.g., product certification and public demonstration).
- Check the domain definition and whether the product is considered to be new or a modification and enhancement.
- Identify the collection of task sheets representing the WBS that will be utilized by the estimation tool. Sum up the efforts on these task sheets that correspond to the estimation tool outputs.
- Review the definition and computation of application complexity. Specifically look for performance criteria and quality attributes that may represent specific baseline attributes in the estimation tool knowledge base. This step is important because there may be inconsistencies between the proposer's use of terminology and the tool's knowledge base use of the same terms. For instance, some performance requirements might use the phrase "real time" to mean "very fast" where the normal interpretation is "deadline driven."
- Review "Manager's Checklist for Validating Software Cost and Schedule Estimates" (Park, 1994) to confirm satisfaction with the contractor's estimation process and resulting basis of estimate.
- Document the size estimate and the knowledge base factors to be applied for each component that will be estimated. The size values should be the current baseline product, proposed reuse, modification, and new development. Use of proxy measures such as ESLOC will add uncertainty to the estimate.

At the completion of this step, you should be ready to supply the parametric inputs in the next step.

Step 2: Match Proposer's Estimate

The purpose of this step is to use the parametric tool to produce an estimate that matches the contractor's estimate as closely as possible. The estimates should match, within a small difference on size, effort, schedule, and defects. Many different parameters must be tested to achieve a satisfactory result.

Perform the following activities during this step:

- Clearly identify as much of product context as the tool allows. Most tools allow specification of product domain (e.g., avionics), development methodology, and development language.
- Begin by entering base, new, modified, and deleted size estimates. ESLOC can be used as a last resort, but this increases the uncertainty in the estimate. It is not possible to use an ESLOC value to back out the base, new, modified, and deleted values.
- Record additional estimation tool parameter values such as
    - available tools and platforms,
    - experience of team members in both development and architecture,
    - organizational process maturity,
    - quality assurance and testing, and
    - factors affecting team performance, such as cohesion and geographical proximity.

  Detailed familiarity with the parametric tool is required for this step. DoD contractors are and will claim to be high-caliber development organizations. Interviews are a good mechanism for obtaining the parameter values, but experience and judgment are necessary for trustworthy results.
- Modify the parameter values of the baseline to match the contractor estimate. This step may be difficult and tedious. Even a fairly simple tool like COCOMO II has 22 factors affecting productivity plus various sizing factors. Once the initial estimate is prepared with contractor sizing and product domain information, it is time to match the contractor estimate by adjusting quality and productivity parameters.
- Save the matched estimate as a baseline.

If no reasonable match can be made, then it is time to re-check the Park (1994) checklist and re-interview the contractor. Most likely, there is a misinterpretation of some size measure, knowledge base parameter, or performance parameter. It is also possible that the contractor's WBS has been misinterpreted.

Step 3: Perform Sensitivity Analysis

The sensitivity analysis is necessary in order to make concrete suggestions about productivity improvements. Productivity parameters will include such factors as team cohesion, developer experience, project environment, and process maturity. Product quality parameters will address questions about the target environment, testing, and stability of the

specification. Parameters affecting product quality should generally be excluded from the sensitivity analysis unless some error has been identified in the proposal.

- If the tool provides a sensitivity analysis, then use the suggested top 10 parameters for improvement potential. If the tool lacks this capability, it may be necessary to apply brute force or Monte Carlo methods to determine the parameter sensitivity.
- List the parameters to be tested for alternative estimates.

Step 4: Prepare Alternative Estimates

- Re-run estimates with the identified performance criteria set to revised values. The revised values are selected from benchmark data. These values may be taken from the best projects in the tool vendor's database or another source.
- Document the alternative schedule, effort, and defects along with the revised resource allocation (how much effort is suggested for top few roles).
- Save the new baselines with identification.
- Document the changes to the affected parameters.
- Document the differences from the contractor's baseline in schedule, effort, defects, and cost.
- Run a second sensitivity analysis. If the sensitivity analysis suggests significant additional improvements are possible, then repeat this step and develop a second should-cost estimate and proposal.

Summarize the results in a briefing making comparisons of estimated results and alternative parameter values. Associated with each alternative should be a discussion of the rationale for the potential improvements and how they might be achieved. If more than one estimate will be presented, then be prepared to discuss the relative improvement achieved by each.

Step 5: Workshop

The workshop begins with a presentation of the analytical results and concludes with some recommendations for action. A workshop is necessary as the contractor must agree to planning and resourcing to make changes.

- Display the baseline estimate beginning with the usual values: size, effort, schedule, and defects.
- Show the sensitivity analysis used to arrive at the new estimation parameter values.
- Provide the actual list of parameter values applied for the new estimate.
- Display the revised estimate showing the comparison of the values to the baseline.
- Provide comparisons and explanations of initial and revised parameter values.
- Allow contractor evaluation of potential for change.
- Achieve agreement on action items to resource changes.

Results

The SEI participated with AT Kearney (ATK) in a should-cost analysis for the F-22 3.2a contract. The SEI used the method described here and ATK applied bottom-up analysis. Both approaches led to very similar cost savings, which gave the resulting recommendations very strong weight. As a result of this should-cost effort, the program office was able to negotiate a 15% reduction, $32 million cost savings. These results were reported in a recent OSD (2012) publication *Better Buying Power II.*

There were several lessons learned during this effort. Many of the lessons correspond to the recommendations in the aforementioned RAND report.

1. A dedicated independent team is needed. This team was focused on the should-cost effort and not distracted by contracting and immediate technical problems.
2. Use of multiple methods for should-cost has value to program. The methods used by ATK and SEI were independent and different. The results were similar and carried a great deal of weight in negotiations because of the independence.
3. A contractor's estimation procedure based solely on historical data is insufficient. Such contractors' estimates may be defensible but miss the opportunity for benchmarking against competition and industry-wide comparisons. Should-cost is a method that requires available benchmarks for both cost and quality and specifically identifies the driving factors behind cost and quality.
4. The contractors' usage of estimation tools must be examined carefully. Contractors may change the cost estimation tool's baseline data in order to match contractor performance history. This approach can compromise the ability to use the parametric model as a baseline. Using the parametric model as a benchmark required significant analysis to arrive at a baseline value that matched the contractor's. Contractors had misinterpreted some input productivity factors and adjusted the output calculations instead.
5. Not all parameters are easy to identify. For example, SEER makes use of a parameter that can be used to account for independent development teams when size has not been partitioned to the component level in the estimate. Partitioning the work allows for a more aggressive schedule estimate since teams are able to operate independently until integration testing. This may be difficult to detect from the available documentation.
6. Consider the effects of adding automation or tooling to testing and other process changes. Cost savings are often made possible by making process changes; however, process changes can take time to execute. Some savings that were suggested in the F-22 analysis were not achievable within the time horizon of the 3.2a effort. Recommendations will be accepted or rejected as part of the negotiation process.

There were a number of reasons to consider the F-22 analysis a success. The government certainly was happy to negotiate a better price. Even though some of the work between analysts and contractors was contentious, the contractors were able to agree to a number of suggested improvements. An additional should-cost analysis was also conducted for the next contract block. The second time through there was already evidence of improved performance and much less contention during the analysis.

It will be a while before the final numbers are available from the F-22 modernization work. Hopefully, that will also be a success story.

References

Boito, M. (2012). *The Air Force's experience with should-cost reviews and options for enhancing its capability to conduct them.* Retrieved from http://www.rand.org/pubs/technical_reports/TR1184.html

Camp, R. C. (1989). *Benchmarking: The search for industry best practices that lead to superior performance.* Asq Press.

Carter, A. (2010, June). *Better buying power.* Retrieved from http://www.acq.osd.mil/docs/USD(AT&L)_Memo_to_Acquisition_Professionals_June_28_2010.pdf

Office of the Secretary of Defense. (2012). *Better buying power II.* Retrieved from http://www.acq.osd.mil/docs/BBP Fact Sheet (13 NOV) Final.pdf

Park, R. (1995). *Manager's checklist for validating software cost and schedule estimates, A* (CMU/SEI-95-SR-004). Retrieved from Carnegie Mellon University, Software Engineering Institute website: http://www.sei.cmu.edu/library/abstracts/reports/95sr004.cfm

Womack, J. P., Jones, D.T., & Roos, D. (1990). *The machine that changed the world.* Scribner.

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